Wolf, André

Article

Framework Conditions for Net-Zero Industry Clusters in Europe

Intereconomics

Suggested Citation: Wolf, André (2024) : Framework Conditions for Net-Zero Industry Clusters in Europe, Intereconomics, ISSN 1613-964X, Sciendo, Warsaw, Vol. 59, Iss. 5, pp. 267-275, https://doi.org/10.2478/ie-2024-0054

DOI: 10.2478/ie-2024-0054

Forum

sciendo

Intereconomics, 2024, 59(5), 267-275

JEL: L52, O14, O18

André Wolf

Framework Conditions for Net-Zero Industry Clusters in Europe

With the Net-Zero Industry Act (NZIA) being approved and a set of innovation initiatives under way, the EU has finally taken an industrial perspective on its ambitious decarbonisation goals (European Union, 2024). It is based on the insight that the green transformation of industry is not limited to an exchange of energy sources but involves entirely new supply chains for climate-friendly technologies. On many global markets for key net-zero technologies like batteries and solar cells, European manufacturers play only a minor role in terms of both market share and innovative strength (European Commission, 2023). Without enhancing competitiveness in these new key industrial segments, the European growth model is at risk of persistent external dependencies and being reduced to occupying a place on the technological periphery.

The option provided by the NZIA of introducing special public support schemes for future regional centres of production, so-called net-zero acceleration valleys, could trigger a catch-up process. However, successful industry clusters are not created on a drawing board. In addition to politically controllable factors, such as infrastructure quality, their existence depends on agglomeration advantages arising from the co-location decisions of related industries. Sustainable growth results from the interplay of these factors. Successful cluster policies require policymakers to stimulate this interplay through targeted instruments that support regional networking and address existing bottlenecks.

So far, little attention has been paid to the potential characteristics and locations of future net-zero industry clusters in Europe. This article sheds light on the spatial nature of the competitiveness issue by providing a systematic overview of relevant location factors and their spatial distribution in Europe.

Cluster economics

Spatial clustering of production activities offers a range of benefits like local access to specialised input suppliers, a large labour market pool and enhanced exchange of tacit knowledge (Henderson, 1997). Despite these well-known economic advantages, there are limits to agglomeration incentives. The limits stem from, firstly, the increased cost of immovable assets, such as land, caused by high demand in agglomeration regions. Secondly, the nature of agglomeration advantages as externalities harbours the danger of free riding. Individual companies might seek to profit from local knowledge networks while trying to prevent the outflow of their own exclusive knowledge (Wolman & Hincapie, 2015). As a result, the level of industrial agglomeration may be insufficient from a welfare perspective.

Against this background, the theory and practice of policy-induced industrial clustering has enjoyed great popularity in Europe for some time. Its founding father Michael Porter sees regional clustering as a condition for exploiting national competitive advantages (Porter, 2011). This school stresses the active roles of location policies and collaboration between local networks in shaping and maintaining successful clusters (Hospers & Beugelsdijk, 2002).

Nowadays, cluster strategies are omnipresent in regional policymaking across Europe. This involves decisions on support measures to maintain and further develop existing clusters. In theory, with perfect information and policymakers intent on maximising social welfare, regional competition would lead to an optimal spatial distribution of clusters. Under these conditions, policymakers would align the level of public cluster support with the extent of positive agglomeration externalities expected (Neumark & Simpson, 2015). In practice, the nature and limitations of externalities (and their regional disparity) are largely unknown. An uncoordinated subsidy competition between regions thus threatens to cause not only a waste of resources but also socially suboptimal spatial agglomeration patterns.

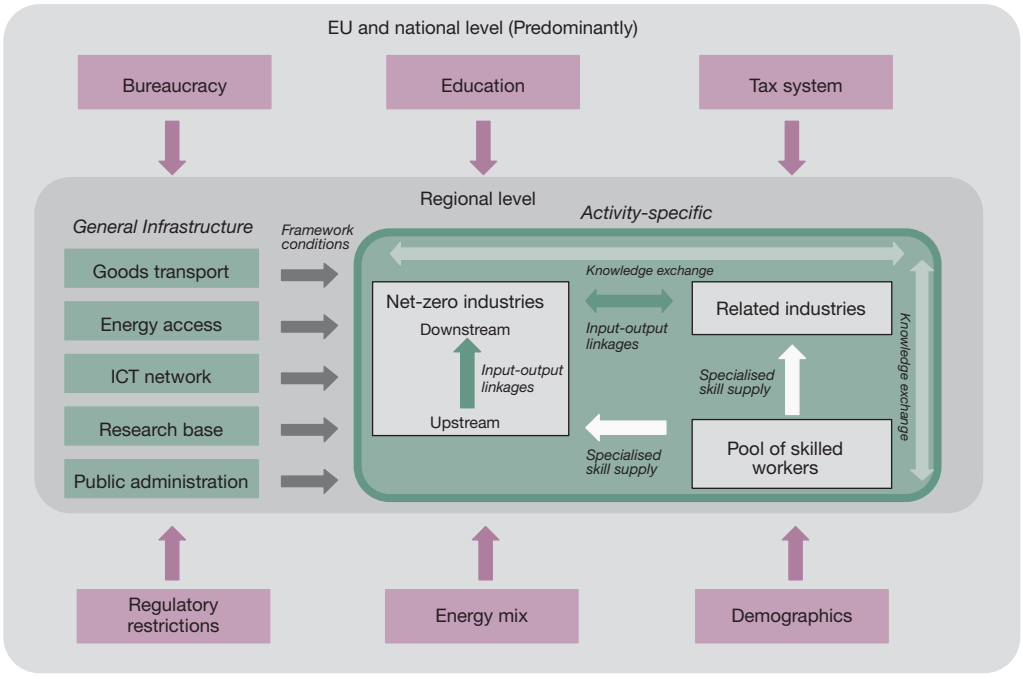
Empirical evidence (Engel et al., 2013; Falck et al., 2010; Graf & Broekel, 2020; Lehmann & Menter, 2018) stresses that the evaluation of cluster policies requires careful scrutiny of the local circumstances and the adequacy of support measures chosen. The uniqueness of the local economic structure, e.g. its business tradition and the specific skills of its workforce, must be respected by any cluster strategy.

Environment for net-zero technology clusters

The variety of technologies currently viewed as "strategic" for implementing the green transformation complicates the identification of relevant location factors. Nevertheless,

André Wolf, Centre for European Policy, Berlin, Germany.

Figure 1
System of fundamental location factors for net-zero industry valleys



Source: Author's own illustration.

certain commonalities can be highlighted. Most net-zero technologies are only at an early stage of their life cycle. There is the prospect of significant future cost reductions as a result of scaling and technological improvements. This requires continuous optimisation of supply chains, which is facilitated by stable relationships with regional input suppliers. Moreover, the novelty of the technologies places specific demands on the qualifications of the workforce, requiring a large regional pool of specialised labour. A dense local network of related industries could therefore represent an important locational advantage.

In addition, the high knowledge intensity of net-zero technologies creates the need for a high-quality regional research infrastructure. The literature shows that the presence of research-intensive universities and research institutes in regional clusters can increase general innovation activity and boost R&D productivity (Hewitt-Dundas, 2013). They serve as a nucleus for new entrepreneurial activity to market regional innovations (Carree et al., 2014).

Local energy supply is likewise critical for net-zero technologies. Their net-zero status hinges on sufficient access to renewable energy sources. Currently, delays in the expansion of electricity grids are inhibiting the European integration of electricity markets (Pietzcker et al., 2021). The local generation potential of electricity from renewables could therefore become a limiting factor for the emergence of net-zero technology clusters.

In addition, location factors with general relevance for high-tech manufacturers matter as well. One of these is IT connectivity, due to the need for continuous information exchange within factories and along supply chains (First-Light, 2024). Moreover, the existence of a well-developed regional transport infrastructure (roads, railways, harbors, flight connections) is important for reducing trade costs. Finally, the quality of local public administration services (speed, reliability) affects the speed of approval procedures and the business-friendly implementation of national and EU-wide laws. Figure 1 summarises the factors discussed in a multi-level system. In what follows, we attempt to assess these factors for EU regions.

Public infrastructure quality in EU regions

The location factors that determine a region's general infrastructure quality are measured first. Where possible, we rely on Eurostat as a reliable database (Eurostat, 2024), supplemented by other public sources. As a territorial unit, we choose the NUTS 2 level for reasons of data availability.

Table 1 shows the selected indicators for each infrastructure category. For the "goods transport" category, we uti-

Table 1
Overview on infrastructure indicators

Category	Indicator	Meaning	Source
Transport	Density of motorways	Average density of motorways (km per km² area) in the region and neighbouring regions in 2021	Eurostat (2024)
	Density of railways	Average density of railways (km per km² area) in the region and neighbouring regions in 2021	Eurostat (2024)
	Daily flight passengers	Average number of daily flight passengers in 2022	Eurostat (2024)
ICT	Broadband access households	Share of private households with access to broadband internet in 2021	Eurostat (2024)
	Broadband access enterprises	Share of enterprises with access to broadband internet in 2021	European Union (2022)
	High-speed internet	Share of population with high-speed internet connection in 2021	European Union (2022)
Research base	Human resources in science and technology	Number of employees in science and technology per capita in 2023	Eurostat (2024)
	Public R&D expenditure	Public expenditure for research and development per capita in 2022	European Union (2023)
	Scientific publications	Number of publications in international scientific journals by researchers in the region per capita in 2023	European Union (2023)
Public administration	Prevention of corruption	Prevention of corruption in regional public administration according to a survey-based index in 2024	Charron et al. (2024)
	Quality and accountability	Quality and accountability of regional public administration according to a survey-based index in 2024	Charron et al. (2024)
	Impartiality	Impartiality of regional public administration according to a survey-based index in 2024	Charron et al. (2024)

Source: Author's own representation.

lise Eurostat data on the density of transport networks. The quality of ICT networks is reflected by indicators from the EU Regional Competitiveness Index (European Union, 2022). To map the research base, we draw on data from the EU Regional Innovation Scoreboard (European Union, 2023). For the quality of regional public administration, we rely on the results of regular surveys for the European Quality of Government Index (EQI) (Charron et al., 2024). Energy access represents a special case in view of the energy transition. Due to the uncertainty concerning future local supply conditions, we do not integrate it in our index, but consider the local potential of electricity generation from renewables as a separate limiting factor. For this, we draw on estimates by Kakoulaki et al. (2021).

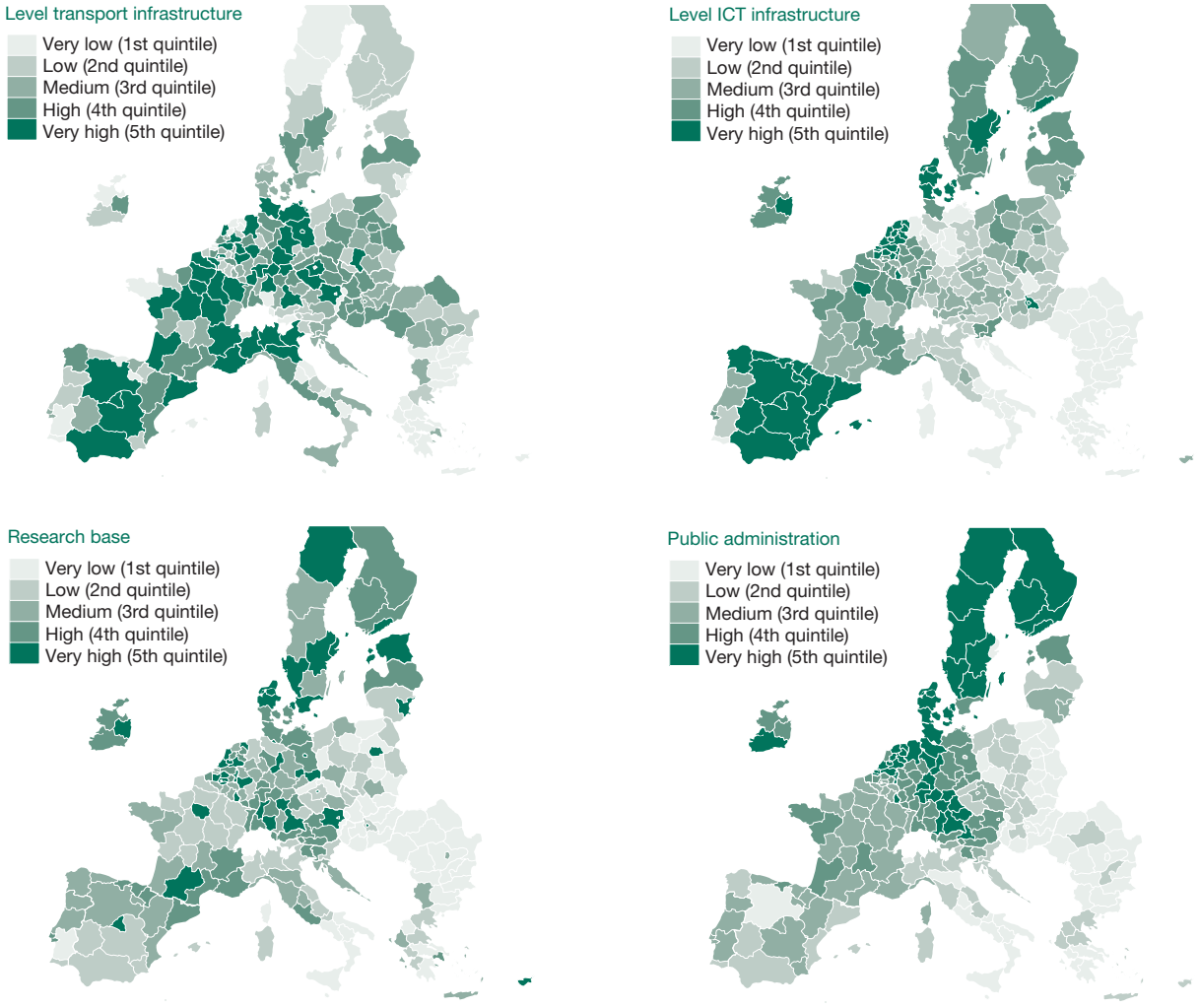
The individual indicators are aggregated in weighted form into the respective categories. Following a procedure common in the literature, we determine the weighting on the basis of a (category-specific) Principal Component Analysis (PCA). The indicators are included in the PCA in standardised format. In each case, we select the loadings of the first factor as the basis for the weighting. This results in four infrastructure indices.

The resulting regional distributions of the index scores are illustrated in Figure 2 as quintiles. Apart from a general west-east divide, it reveals a nuanced pattern. While the transport infrastructure is rated as particularly good in economic core regions, there is little correlation to existing agglomeration patterns in the other infrastructure dimensions. Regarding ICT quality, country differences are particularly striking. Spain, Denmark and the Benelux countries achieve high coverage with broadband access nationwide. In contrast, the industrial regions of Germany and Italy only achieve below-average values in some cases. In the area of administrative quality, the Scandinavian countries are almost universally found among the top 20%. A large part of the Benelux region and parts of Germany are also among the top performing regions. The assessment of the research base, on the other hand, points strongly to regional centres within the member states.

To obtain an aggregate measure of infrastructure quality, different kinds of weighting and aggregation processes are conceivable. Companies from different net-zero industries will differ in the specific weight they place on certain infrastructure categories. Yet, it is generally plausible that the different categories are not considered perfect substitutes, given the distinct kinds of infrastructure services they provide. We reflect this idea through a multiplicative aggregation (geometric average) of the values in the four infrastructure sub-indices.

The resulting top 10 regions are shown in Table 2. These regions are concentrated on four member states: Germany, France, Denmark and the Netherlands. These regions share above-average performance in almost all categories. Some, but not all, of them are already important

Figure 2
Results of infrastructure sub-indices in EU regions



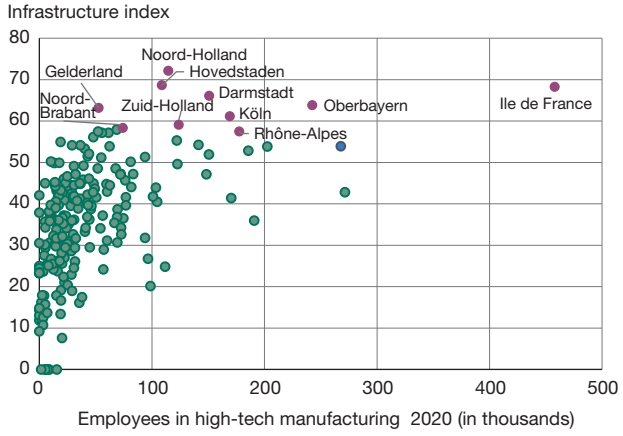
Source: Author's own calculations.

Table 2
Top ten EU NUTS 2 regions in infrastructure quality (index values)

Rank	NUTS	Region	Transport infrastructure	ICT infrastructure	Public administration	Research base	Total (geom. av.)
1	NL32	Noord-Holland	64.18	99.34	69.05	61.54	72.14
2	DK01	Hovedstaden	32.43	86.30	79.35	100.00	68.65
3	FR10	Ile de France	100.00	85.32	48.72	52.22	68.26
4	DE71	Darmstadt	93.02	69.00	71.35	41.65	66.08
5	DE21	Oberbayern	68.64	54.75	72.00	61.29	63.81
6	NL22	Gelderland	41.99	96.37	78.16	50.30	63.16
7	DEA2	Köln	58.81	63.08	65.33	57.60	61.13
8	NL33	Zuid-Holland	31.82	98.75	72.97	53.16	59.09
9	NL41	Noord-Brabant	41.46	96.13	71.65	40.53	58.33
10	FRK2	Rhône-Alpes	78.75	64.74	57.80	37.03	57.47

Source: Author's own calculations; Index values standardised from 0 (lowest value) to 100 (highest value).

Figure 3
Comparison of infrastructure quality and high-tech manufacturing in EU regions



Source: Eurostat (2024); author's own calculations.

centres for high-tech production throughout Europe (see Figure 3). Conversely, however, not all the important high-tech locations exhibit above-average infrastructure quality. Counterexamples include Lombardia (ITC4) and Lazio (ITI4), which are only in the midfield.

Local industry linkages in EU regions

Measuring the extent of regional industry linkages is a difficult task, due to the diversity of input requirements of different net-zero technologies. Moreover, European sectoral statistics do not allow for a clear delineation of economic activities identifiable as net-zero. We have therefore chosen an alternative indirect approach for our analysis based on the use of US data. The regional datasets regularly published by the U.S. Bureau of Economic Analysis (BEA) are characterised by a much finer granularity than European sources such as Eurostat. We apply the methodology used by Delgado et al. (2016) to identify clusters of technologically closely related industries. It is based on the calculation of multidimensional similarity matrices to evaluate the pairwise similarity of industries. Based on these matrices, individual industries are grouped into disjointed clusters using established methods of cluster analysis.

The first step is to identify the sectors of the North American Industry Classification (NAICS) containing net-zero technologies. The 2017 version of the NAICS comprises a total of 1,057 different industries (so-called national industries). Our classification of these national industries as net-zero technologies is based on a comparison of the content descriptions found in NAICS documentation with the list of specifically named net-zero technologies from the NZIA (European Union, 2024). On this basis, we identify a total of nine NAICS industries that clearly involve production of net-zero technologies, either in total or in part. They are henceforth termed "NZT industries".

Table 3 shows the list of industries and their relevance for specific items on the NZIA list. Since other NAICS indus-

Table 3
Identified net-zero technology industries in the North American Industry Classification

NAICS Code	Title	Example(s) of relevant products	Relevant item(s) on NZIA list
333415	Heating equipment (except warm air furnaces) manufacturing	Heat pumps	Heat pumps and geothermal energy technologies
333611	Turbine and turbine generator set units manufacturing	Wind turbines	Onshore wind and offshore renewable technologies
333912	Air and gas compressor manufacturing	CO_2 compressor for carbon capture and storage; compressors for transport of hydrogen or biogas	Carbon capture and storage technologies; hydrogen technologies; sustainable biogas and biomethane technologies; CO_2 transport and utilisation technologies
333994	Industrial process furnace and oven manufacturing	Low-emission metal melting (e.g. hydrogen-, biogas-based crude steel production)	Hydrogen technologies; sustainable biogas and biomethane technologies
334413	Semiconductor and related device manufacturing	Photovoltaic cells, -modules; fuel cells	Solar technologies; hydrogen technologies
334515	Instrument manufacturing for measuring and testing electricity	Power measuring equipment	Electricity grid technologies
335311	Power, distribution and specialty transformer manufacturing	Power transformers (voltage regulators)	Electricity grid technologies
335911	Storage battery manufacturing	Batteries for electric cars / large-scale energy storage	Battery and energy storage technologies
335929	Other communication and energy wire manufacturing	Electrical cables	Electricity grid technologies

Source: Author's own representation.

Table 4
Results of cluster analysis

NAICS code	NAICS title	NACE equiv. (code)	NACE equiv. (title)
Technology Cluster 1			
3321	Fabricated metal product manufacturing	C25	Manufacture of fabricated metal products
3331	Machinery manufacturing (other than NZT industries)	C28	Manufacture of machinery and equipment n.e.c
333415	Heating equipment (except warm air furnaces) manufacturing	C28	Manufacture of machinery and equipment n.e.c
333611	Turbine and turbine generator set units manufacturing	C28	Manufacture of machinery and equipment n.e.c
333912	Air and gas compressor manufacturing	C28	Manufacture of machinery and equipment n.e.c
333994	Industrial process furnace and oven manufacturing	C28	Manufacture of machinery and equipment n.e.c
3366	Ship and boat building	C30	Manufacture of other transport equipment
3369	Other transport equipment	C30	Manufacture of other transport equipment
3371	Furniture manufacturing	C31	Manufacture of furniture
3391	Medical equipment and supplies manufacturing	C32	Other manufacturing
3399	Miscalleneous	C32	Other manufacturing
Technology Cluster 2			
334413	Semiconductor and related device manufacturing	C26	Manufacture of computer, electronic and optical products
3351	Electric lighting equipment manufacturing	C27	Manufacture of electrical equipment
335311	Power, distribution, and specialty transformer manufacturing	C27	Manufacture of electrical equipment
3353	Electrical equipment manufacturing (other than NZT industries)	C27	Manufacture of electrical equipment
335911	Storage battery manufacturing	C27	Manufacture of electrical equipment
3359	Other electrical equipment and component manufacturing (other than NZT industries)	C27	Manufacture of electrical equipment
335929	Other communication and energy wire manufacturing	C27	Manufacture of electrical equipment
Technology Cluster 3			
3341	Computer and peripheral equipment manufacturing	C26	Manufacture of computer, electronic and optical products
334515	Instrument manufacturing for measuring and testing electricity	C26	Manufacture of computer, electronic and optical products
3346	Manufacturing and reproducing magnetic and optical media	C26	Manufacture of computer, electronic and optical products
3364	Aerospace product and parts manufacturing	C30	Manufacture of other transport equipment

Source: Author's own calculations. Net-zero technology (NZT) industries are highlighted in green.

tries may also contain relevant components, and the set of net-zero industry technologies is constantly evolving, it should be understood as a minimum core list.

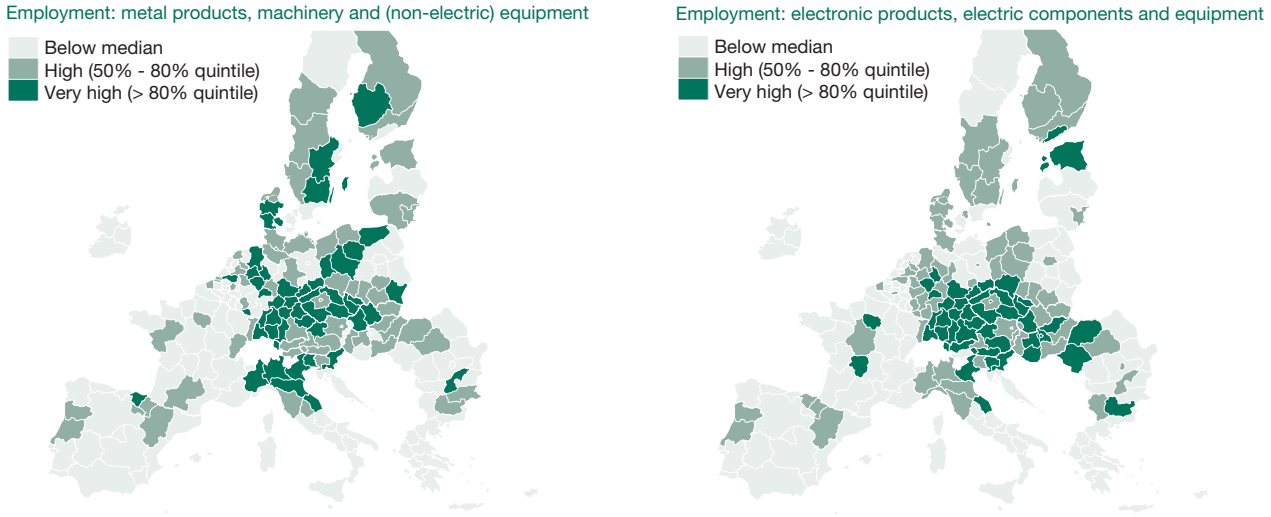
To measure the degree of similarity between industries with regard to supply chain linkages, we use the current version of the BEA's national input-output tables (BEA, 2024). We measure the degree of input-related similarity between two industries as a correlation coefficient of value shares of purchased inputs. Likewise, we calculate the output-related similarity as the correlation of value shares of customer industries. Finally, we compute the degree of similarity in labour demand on the basis of data from the Bureau of Labor Statistics (BLS). It shows the number of employees by occupational group in NAICS industries (BLS, 2024). We calculate the correlation between the employment distributions of the different industries.

We then performed k-means cluster analyses for the three individual similarity measures to identify clusters among industries.[1] Sectors that were part of the same clusters as the NZT industries in all three dimensions were considered linked industries. Table 4 summarises the resulting clusters of linked industries. The NZT industries covered are spread over a total of three clusters.

Clusters 1 and 2 are particularly interesting, as they contain various net-zero technologies. To apply our results to the European level, we carry out a mapping of the NAICS industries included in these two clusters to the coarser two-digit level of the EU NACE classification (see last column in Table 4), using the concordance table between

1 For each similarity measure, the optimal number of clusters was chosen based on the silhouette method.

Figure 4
Employment density of identified industry groups in EU NUTS 2 regions (2020)



Source: Eurostat (2024); author's own calculations.

NAICS and ISIC provided by the BEA and the ISIC-NACE concordance provided by Eurostat. This results in an industry group 1 comprising "metal products, machinery and (non-electric) equipment" and an industry group 2 comprising "electronic products, electric components and equipment".

Figure 4 illustrates the distribution of employment intensities in these industry groups as the number of regional employees per capita in 2020. The spatial patterns show a strong similarity, which reflects the important role of inter-industry agglomeration effects and general regional location factors. Large cross-regional bands of intensive industrial activity in the centre of Europe are contrasted with individual local hotspots at the periphery. Regarding the "metal products, machinery and (non-electric) equipment" group, the south and northwest of Germany, northern Italy/southeastern France, the north of Poland and the Czech Republic/Slovakia/Hungary form large cross-regional production centres. In the "electronic products, electric components and equipment" segment, there is an even stronger concentration on Central Europe overall. Parts of Romania and Estonia are important hubs in the east, as is central France in the west.

Summary assessment of EU regions

A comparison of the previous analyses allows for a tentative identification of high-potential regions. If, as the agglomeration literature suggests, general infrastructure quality and the benefits of industry-specific agglomeration jointly determine the attractiveness of a location, regions that stand out in both areas are "natural candidates" for hosting net-zero industry valleys. Table 5 lists such regions for the two industry groups considered. The first column lists regions with exceptionally high (> 80% quantile) values both in relation to infrastructure quality and employment density of the respective industry groups ("excellent conditions"). For both industry groups, this includes several regions in southern Germany. Scandinavian regions are also represented. The second and the third column includes regions that only achieve exceptionally high values in one of the two measures, and fairly high values ($50\% < x < 80\%$) in the other ("good conditions"). This segment includes various regions in Austria and Italy. The highly industrialised regions in Eastern Europe are hardly represented in this segment, as a result of their mostly low infrastructure scores.

A potential limiting factor is energy supply. As argued above, sufficient access to electricity from renewable sources can become crucial for the expansion of production capacities for net-zero technologies. When comparing estimates by Kakoulaki et al. (2021), regions identified as offering excellent or good framework conditions exhibit on average a significantly smaller generation potential for electricity from renewables than the remaining NUTS 2 regions (see Figure 5). This mainly results from the fact that cluster candidates are largely located far away from seacoasts, which are best suited for wind power. Future production centres for net-zero technologies could therefore depend heavily on the inflow of renewable energy from other regions, putting further pressure on grid expansion.

Table 5
Net-zero technology cluster candidates by industry group

Industry group 1: Metal products, machinery and (non-electric) equipment					
Excellent conditions		Good conditions			
Very good infrastructure, very high employment density		Good infrastructure, very high employment density		Very good infrastructure, high employment density	
NUTS	Region name	NUTS	Region name	NUTS	Region name
DE11	Stuttgart	AT31	Oberösterreich	DEA1	Düsseldorf
DE12	Karlsruhe	CZ06	Jihovýchod	DK05	Nordjylland
DE25	Mittelfranken	DE13	Freiburg	FR10	Ile de France
DE26	Unterfranken	DE14	Tübingen	FRJ2	Midi-Pyrénées
DEA5	Arnsberg	DE23	Oberpfalz	NL41	Noord-Brabant
DK03	Syddanmark	DE24	Oberfranken		
DK04	Midtjylland	DE27	Schwaben		
SE12	Östra Mellansverige	DE72	Gießen		
		DE94	Weser-Ems		
		DED2	Dresden		
		DEG0	Thüringen		
		ES21	País Vasco		
		FI19	Länsi-Suomi		
		ITC1	Piemonte		
		ITC4	Lombardia		
		SE21	Småland med öarna		
Industry group 2: Electronic products, electric components and equipment					
Excellent conditions		Good conditions			
Very good infrastructure, very high employment density		Good infrastructure, very high employment density		Excellent infrastructure, high employment density	
NUTS	Region name	NUTS	Region name	NUTS	Region name
CZ01	Praha	AT21	Kärnten	DE30	Berlin
DE11	Stuttgart	AT22	Steiermark	DE71	Darmstadt
DE12	Karlsruhe	AT31	Oberösterreich	DE91	Braunschweig
DE21	Oberbayern	AT33	Tirol	DEA2	Köln
DE25	Mittelfranken	CZ02	Střední Čechy	FI1D	Pohjois- ja Itä-Suomi
DE26	Unterfranken	CZ06	Jihovýchod		
DEA5	Arnsberg	DE13	Freiburg		
FI1B	Helsinki-Uusimaa	DE14	Tübingen		
FR10	Ile de France	DE24	Oberfranken		
		DE27	Schwaben		
		DE72	Gießen		
		DED2	Dresden		
		DEG0	Thüringen		
		EE00	Eesti		
		HU11	Budapest		
		SI04	Zahodna Slovenija		

Source: Author's own calculations.

Discussion

In principle, the new Net-Zero Acceleration Valleys present a welcome opportunity for member states to develop regions with good starting conditions into future production hubs. A dedicated policy strategy can support the development of such clusters. It helps to overcome coordination problems in the location decisions of the newly forming industries and thus facilitates the exploitation of agglomeration externalities. However, an uncoordinated subsidy

Figure 5
Average annual green electricity potential by region type

Source: Kakoulaki et al. (2021); author's own calculations.

competition between European regions must be avoided. It would cannibalise scarce public resources and provoke an inefficient spatial allocation of production capacities across Europe. The EU as a whole will only be successful in gaining competitiveness if the distribution of clusters reflects the true comparative advantages of the regions.

Coordination and cooperation at the European level are essential for such an intelligent specialisation. The Net-Zero Europe Platform introduced by the Net-Zero Industry Act (European Union, 2024) should be developed into a governance institution. Its central tasks should be the coordination of the planning of Net-Zero Acceleration Valleys by the member states and the monitoring of their development. The support provided by EU regional and cohesion policies should be chanelled to strengthen the infrastructure in future Net-Zero Acceleration Valleys. Regarding promotion at the member state level, clear guidelines should be set across the EU to avoid a proliferation of different subsidy schemes. Existing administrative bottlenecks in the regions should also be tackled with EU support. Moreover, to support private demand, the option of a temporary coverage of price gaps between domestic and global production should be explored, with Carbon Contracts for Difference as a potential role model.

Finally, a relevant issue for public acceptance is the long-term impact of cluster policies on spatial economic inequality in Europe. The latest election results in Europe suggest that the distributional effects of transformative policies are contributing to a dangerous strengthening of political extremes. Against this background, it is crucial for policymakers to stress that an intelligent specialisation strategy does not aim to deindustrialise regions outside dedicated clusters. This requires the development of net-zero industry clusters to be embedded in an overarching smart specialisation strategy of Europe's regions. It should build on a European vision of competitive supply chains in a future global trade order. If such a strategy is implemented wisely, net-zero industry clusters can become drivers for Europe's industrial renaissance.

References

BEA. (2024). *Input-Output-Accounts Data*. US Department of Commerce – Bureau of Economic Analysis. https://www.bea.gov/industry/input-output-accounts-data

BLS. (2024). *Occupational and Employment Wage Statistics*. US Bureau of Labor Statistics. https://www.bls.gov/oes/tables.htm

Carree, M., Malva, A. D., & Santarelli, E. (2014). The contribution of universities to growth: Empirical evidence for Italy. *The Journal of Technology Transfer*, *39*(3), 393–414.

Charron, N., Lapuente, V., & Bauhr, M. (2024). *The Geography of Quality of Government in Europe. Subnational variations in the 2024 European Quality of Government Index and Comparisons with Previous Rounds*.

Delgado, M., Porter, M. E., & Stern, S. (2016). Defining clusters of related industries. *Journal of Economic Geography*, *16*(1), 1–38.

Engel, D., Mitze, T., Patuelli, R., & Reinkowski, J. (2013). Does cluster policy trigger R&D activity? Evidence from German biotech contests. *European Planning Studies*, *21*(11), 1735–1759.

European Commission. (2023). Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity. *Commission Staff Working Document*, SWD(2023) 68.

European Union. (2022). *EU Regional Competitiveness Index – Edition 2022*. https://ec.europa.eu/regional_policy/information-sources/maps/regional-competitiveness_en

European Union. (2023). *Regional Innovation Scoreboard*. https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/regional-innovation-scoreboard_en

Eurostat. (2024). *Regional statistics by NUTS classification*. Eurostat Database. https://ec.europa.eu/eurostat/web/regions/database

Falck, O., Heblich, S., & Kipar, S. (2010). Industrial innovation: Direct evidence from a cluster-oriented policy. *Regional Science and Urban Economics*, *40*(6), 574–582.

FirstLight. (2024). *5 Reasons Connectivity Is Vital to High-Tech Manufacturers*. https://www.firstlight.net/5-reasons-connectivity-is-vital-to-high-tech-manufacturers/

Graf, H., & Broekel, T. (2020). A shot in the dark? Policy influence on cluster networks. *Research Policy*, *49*(3), 103920.

Henderson, V. (1997). Externalities and industrial development. *Journal of Urban Economics*, *42*(3), 449–470.

Hewitt-Dundas, N. (2013). The role of proximity in university-business cooperation for innovation. *The Journal of Technology Transfer*, *38*(2), 93–115.

Hospers, G. J., & Beugelsdijk, S. (2002). Regional cluster policies: learning by comparing? *Kyklos*, *55*(3), 381–402.

Kakoulaki, G., Kougias, I., Taylor, N., Dolci, F., Moya, J., & Jäger-Waldau, A. (2021). Green hydrogen in Europe – A regional assessment: Substituting existing production with electrolysis powered by renewables. *Energy Conversion and Management*, 228, 113649.

Lehmann, E. E., & Menter, M. (2018). Public cluster policy and performance. *The Journal of Technology Transfer*, *43*(3), 558–592.

Neumark, D., & Simpson, H. (2015). Place-based policies. *Handbook of Regional and Urban Economics* (Vol. 5, pp. 1197–1287). Elsevier.

Pietzcker, R. C., Osorio, S., & Rodrigues, R. (2021). Tightening EU ETS targets in line with the European Green Deal: Impacts on the decarbonization of the EU power sector. *Applied Energy*, 293, 116914.

Porter, M. E. (2011). *Competitive advantage of nations: creating and sustaining superior performance*. Simon and Schuster.

Wolman, H., & Hincapie, D. (2015). Clusters and cluster-based development policy. *Economic Development Quarterly*, *29*(2), 135–149.